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(56) Documents Cited

EP 0511547 A

US 5119714 A

(58) Field of Search

UK CL (Edition M) E1F FFD FGA FGB FGC

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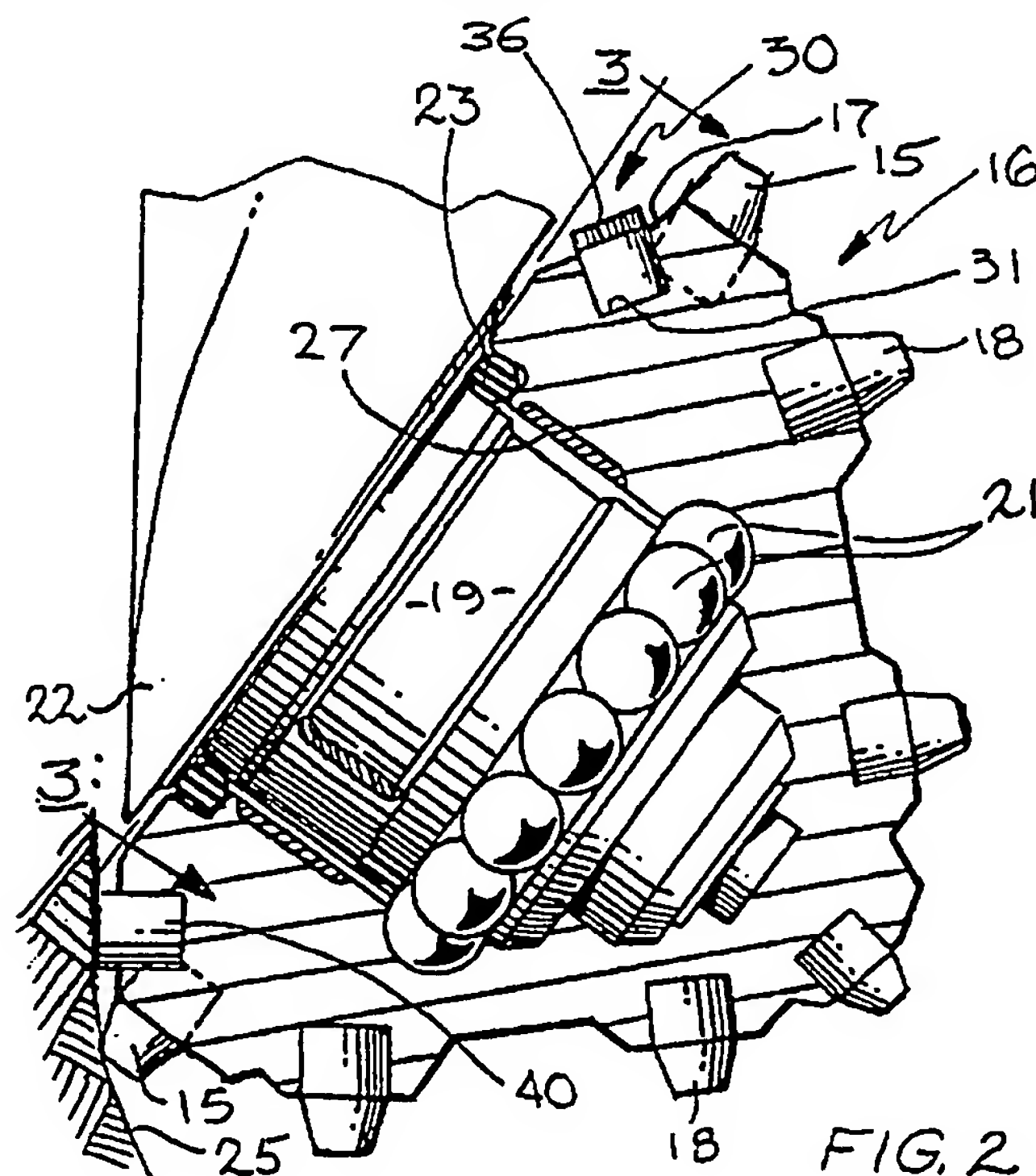
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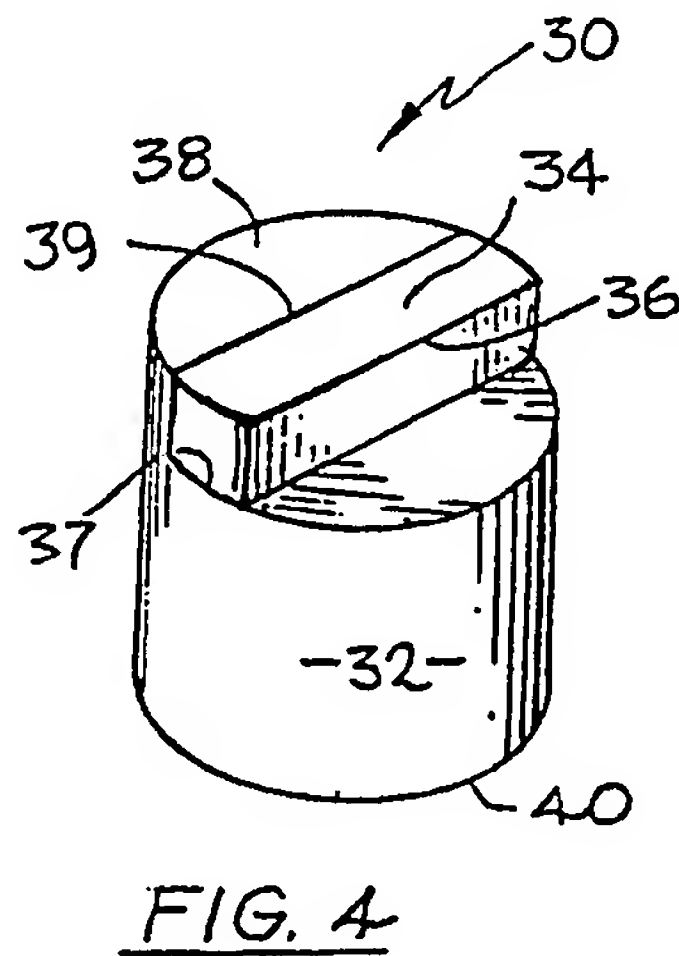
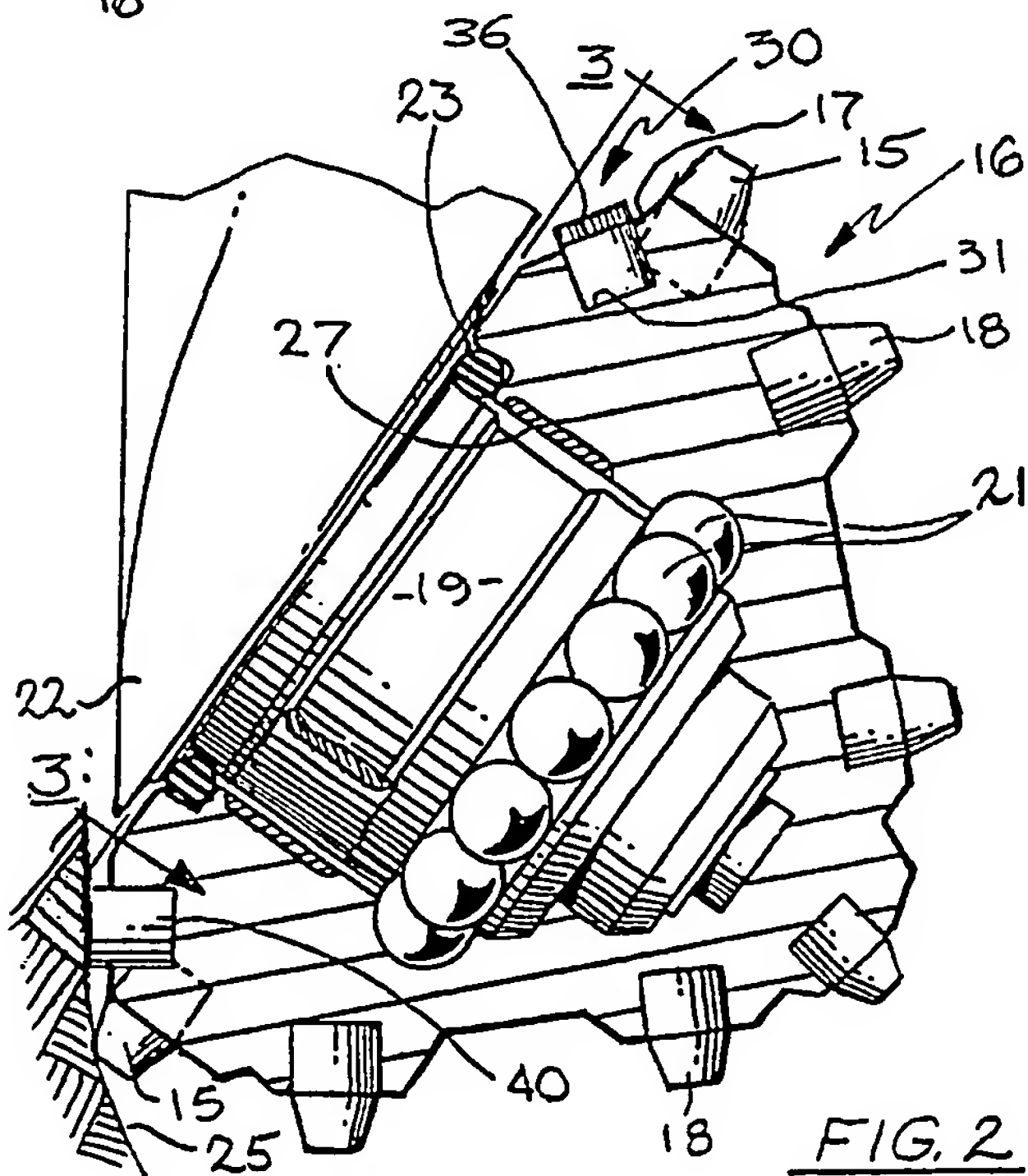
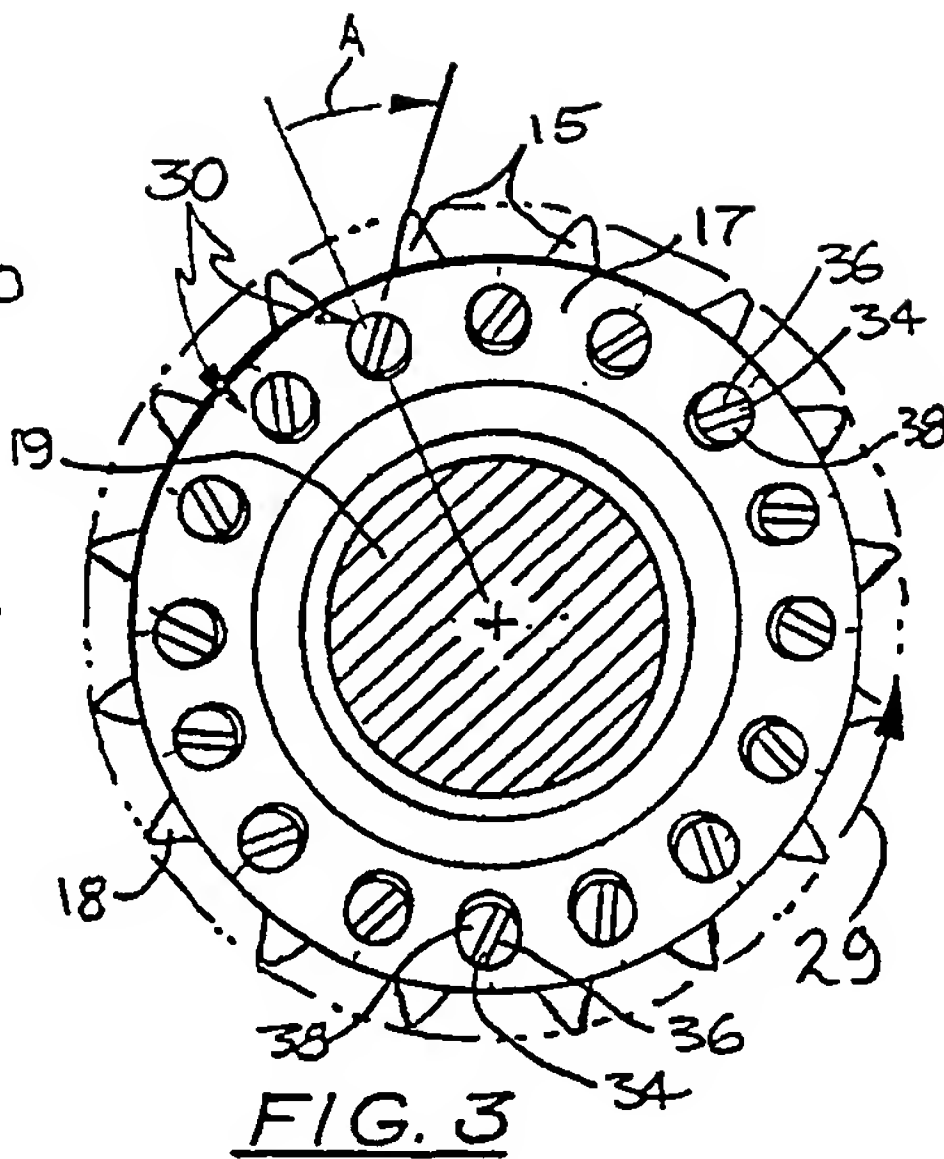
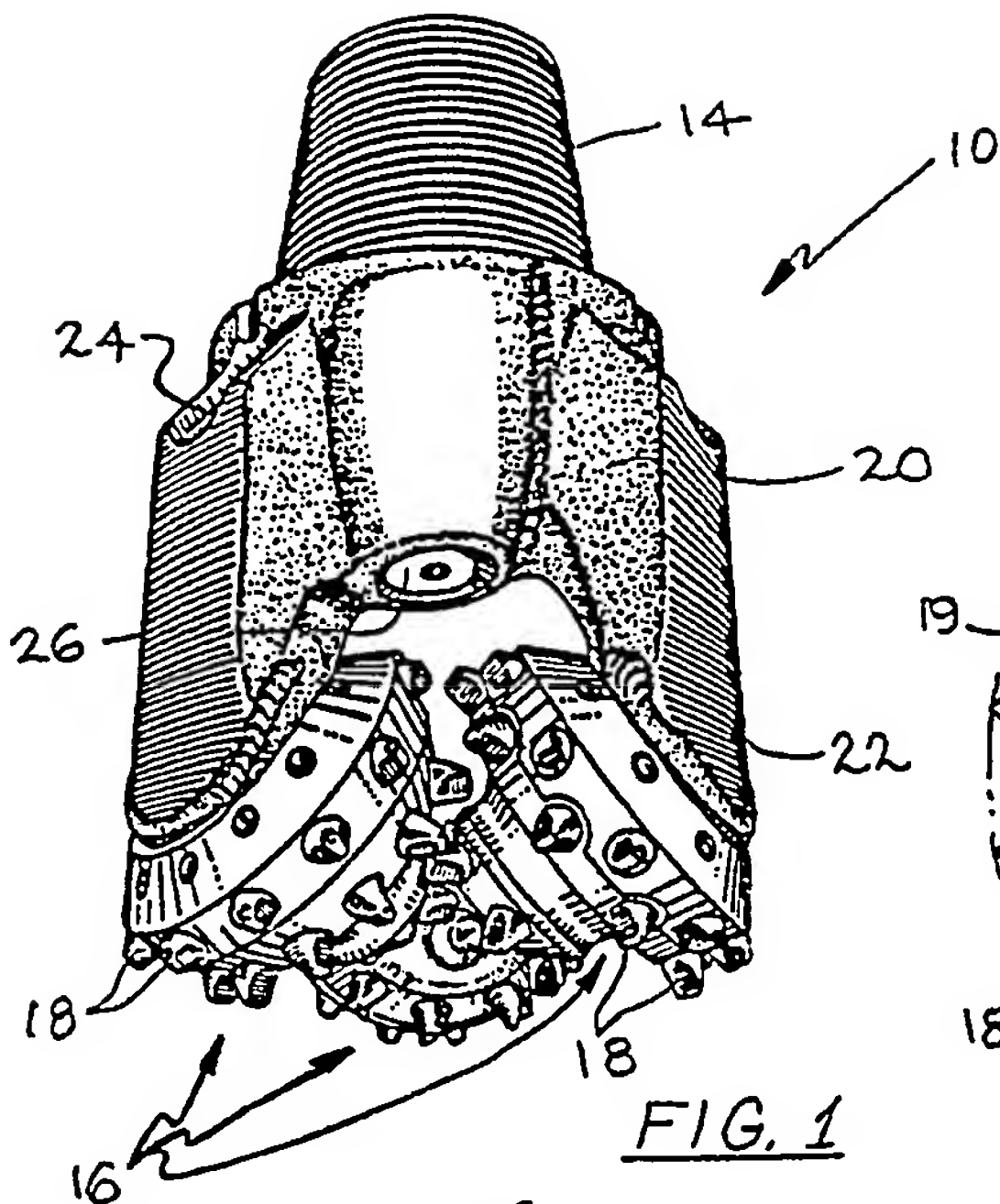
(54) Rotary cone rock bit with ultra hard heel row inserts

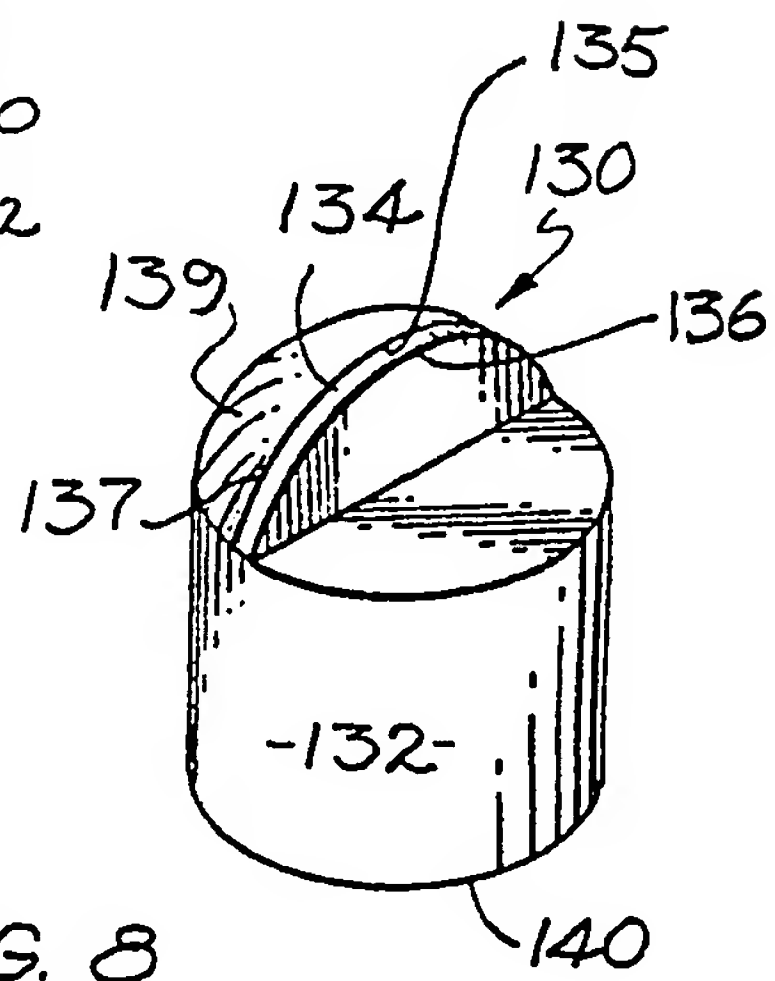
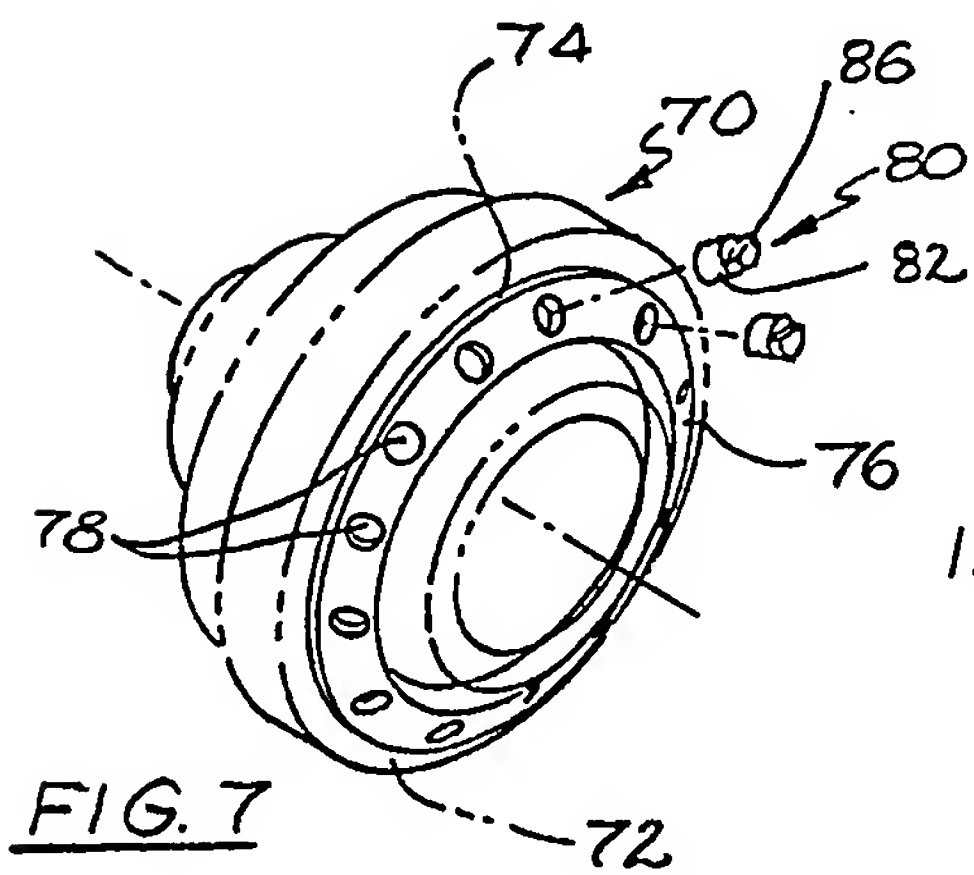
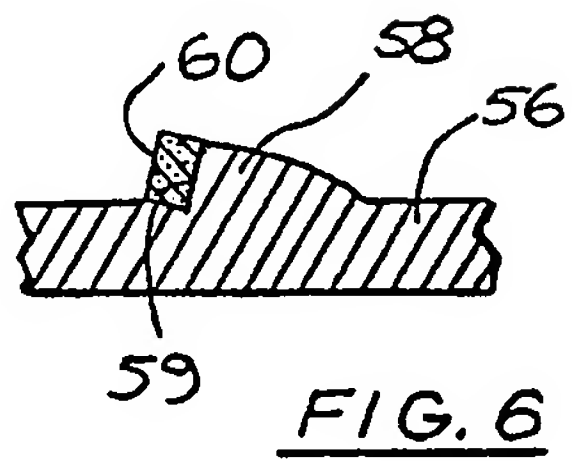
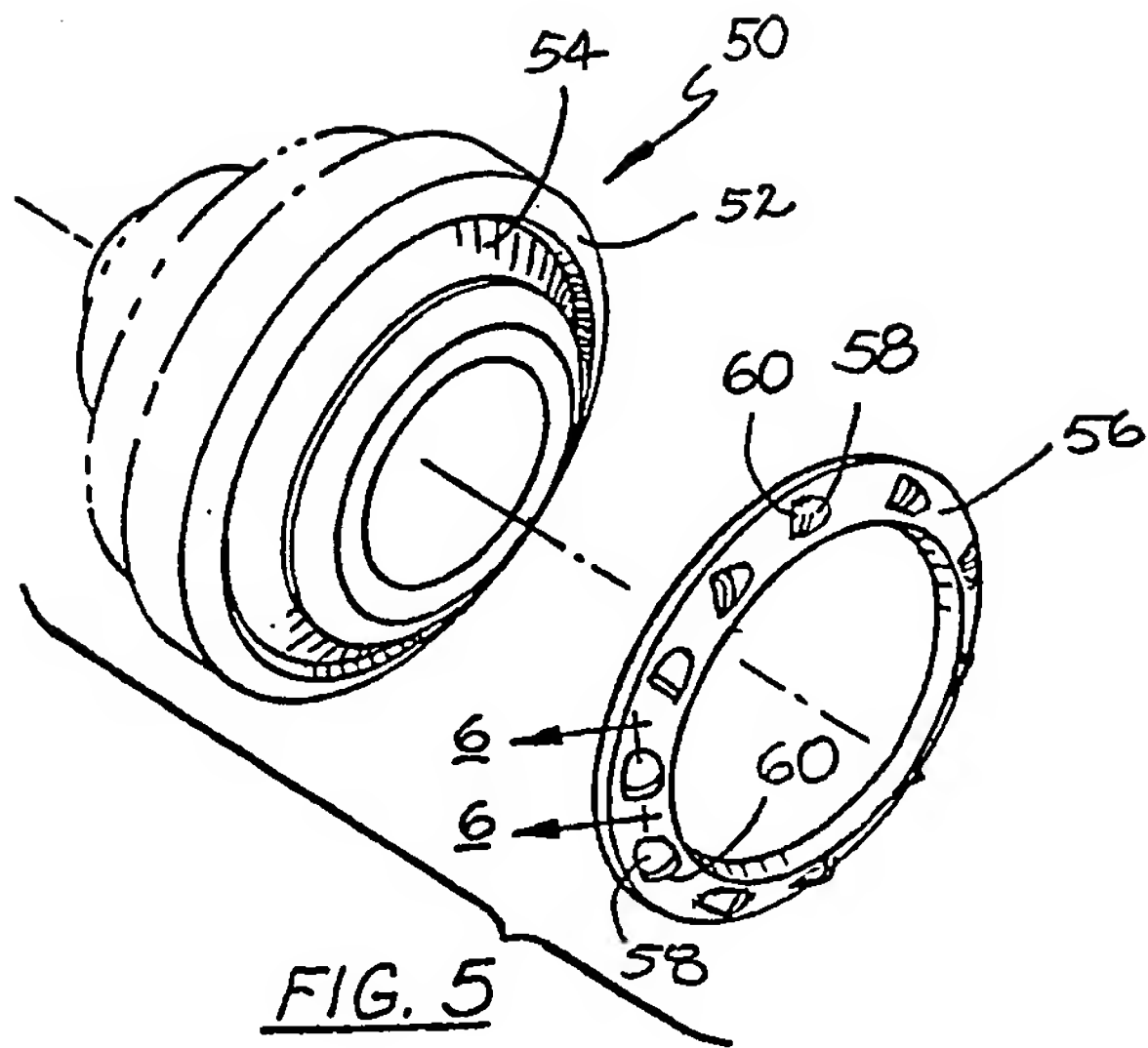
(57) A rotary cone rock bit for drilling boreholes in an earthen formation has one or more rotary cones 16 rotatively retained on a journal bearing 19 connected to the rock bit body. These rotary cones 16 have a plurality of tungsten carbide inserts 18 and a gage row 15 of tungsten carbide inserts for drilling the hole diameter. A circumferential heel row 30 has extended ultra hard shaped cutters spaced within the heel row. Each of the shaped cutters has a cutting edge 36 that shears a borehole wall formed by the formation as the rotary cone rotates against a bottom of the borehole. The shaped cutters serve to maintain the borehole diameter and to divert formation debris away from bearing surfaces formed between the rotary cone and the journal bearing. Preferably the ultra hard cutters have a polycrystalline diamond cutting edge.



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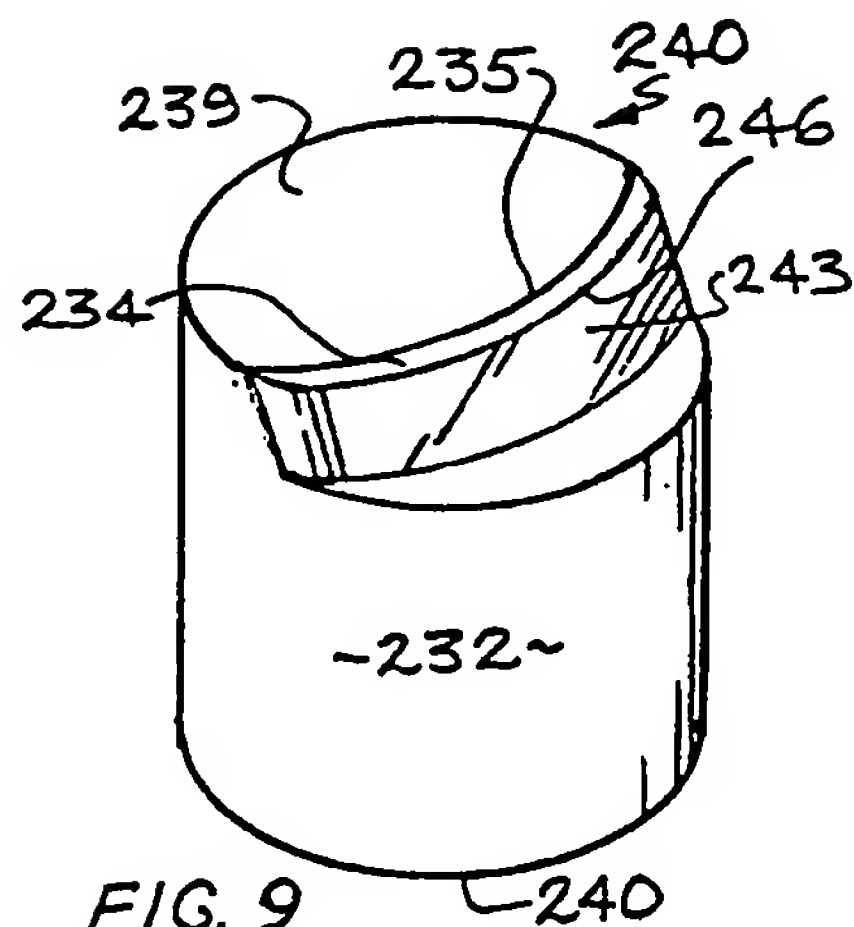


FIG. 9

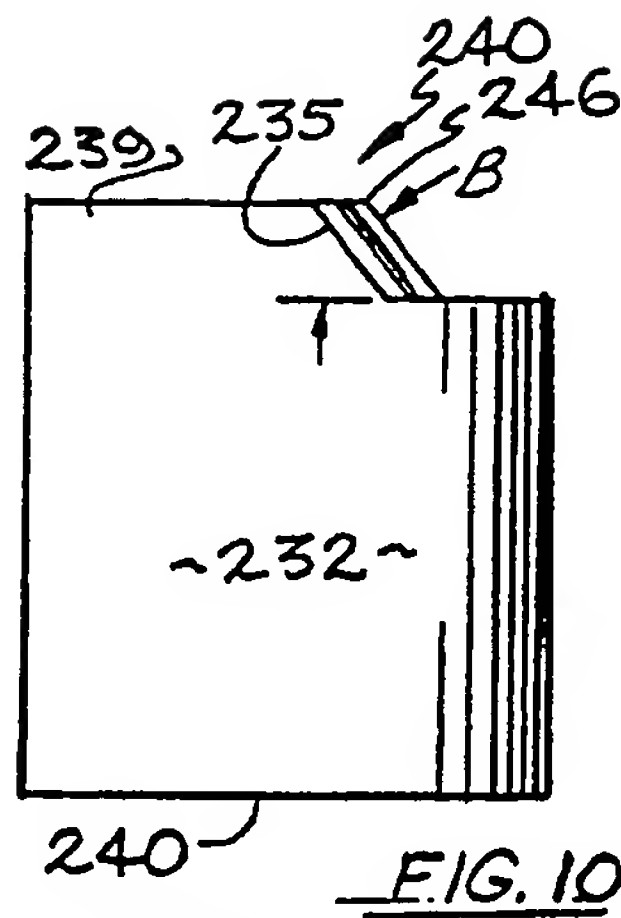


FIG. 10

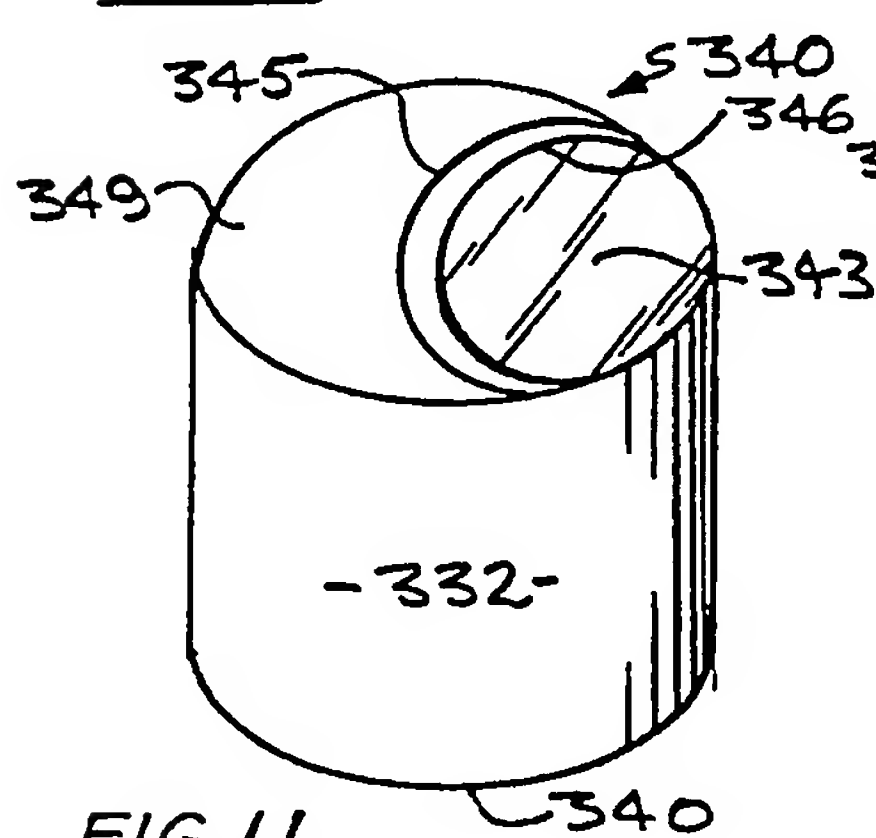


FIG. 11

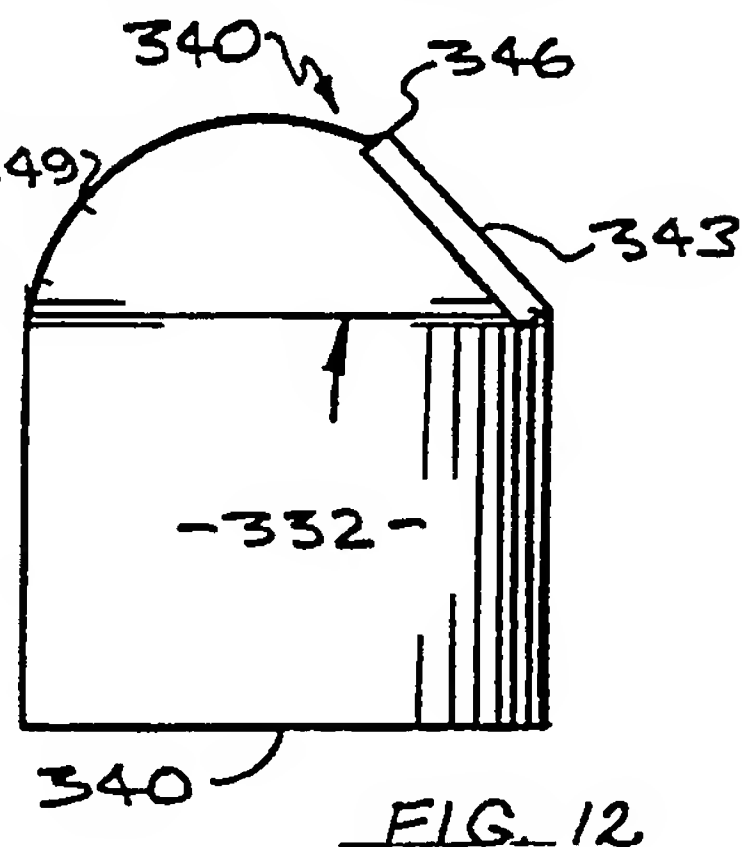


FIG. 12

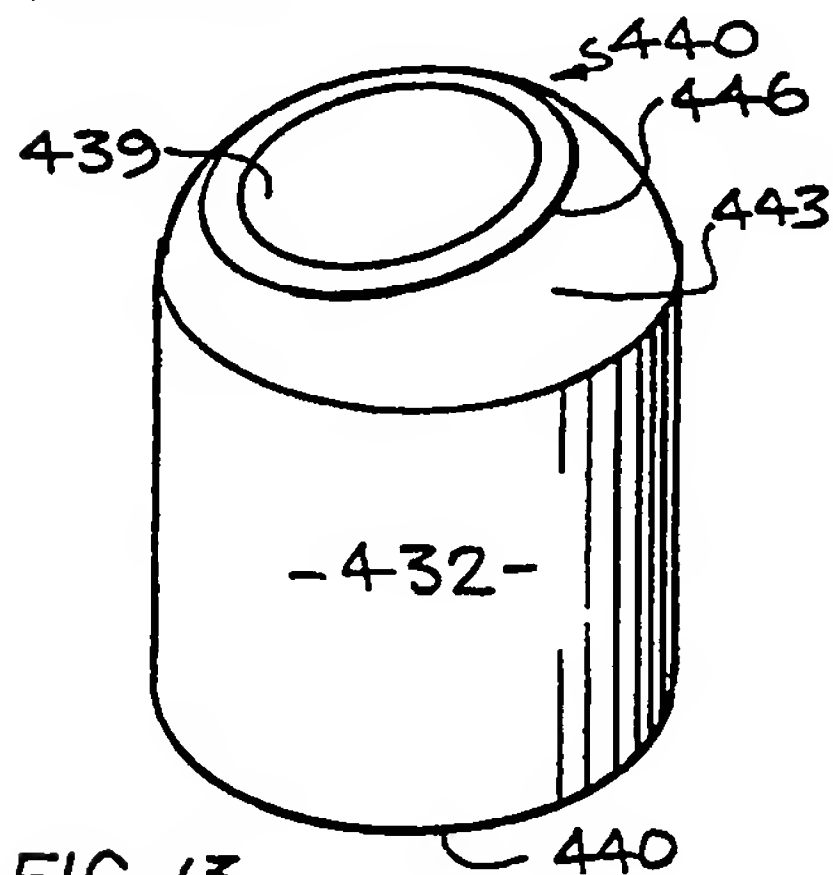


FIG. 13

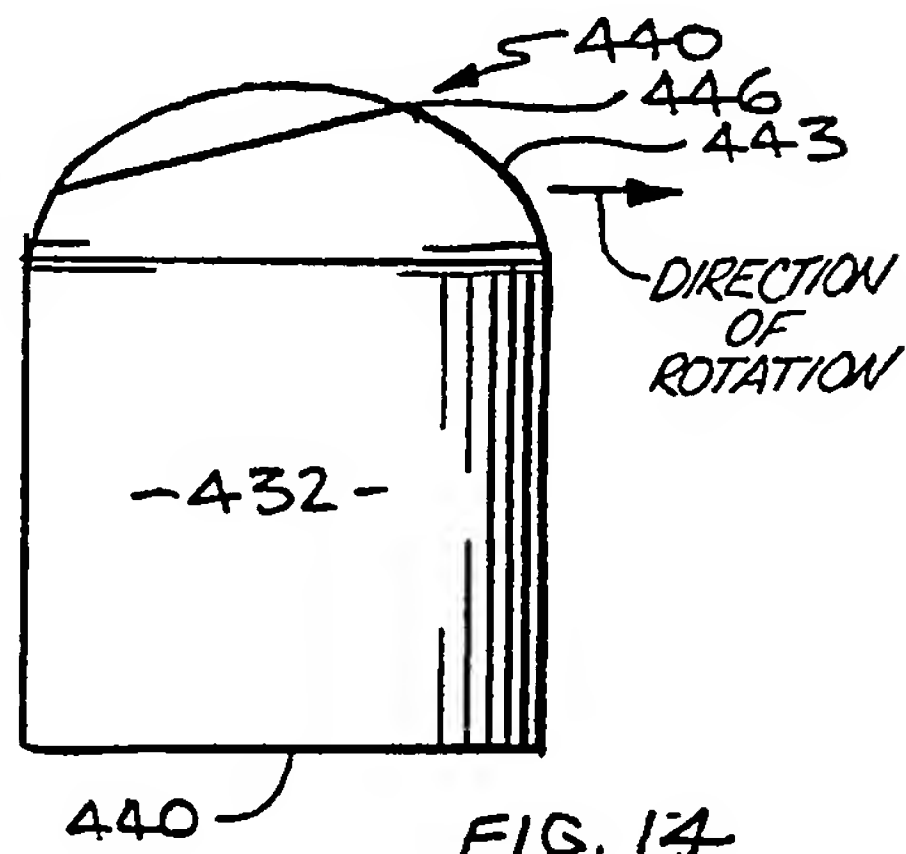


FIG. 14

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ROTARY CONE ROCK BIT
WITH ULTRA HARD HEEL ROW INSERTS

BACKGROUND

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This invention relates to the cutting structure formed on rotary cones of rotary cone rock bits utilized to drill boreholes in an earthen formation. More particularly, this invention relates to the use of shaped diamond or other ultra hard material insert cutters in the heel row of each of the rotary cones associated with the drill bit for shearing and maintaining the gage bore diameter of the formation. These ultra hard materials include cubic boron nitride and/or diamond/refractory metal carbide composites.

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25

Inserts with a polycrystalline diamond surface have been tried before in roller cone rock bits in an attempt to extend the useful life of a rock bit as it works in a borehole.

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35

U.S. Patent Number 4,940,099 teaches the utilization of alternating cemented tungsten carbide inserts and diamond coated inserts in each row formed on a rock bit cutter cone. Both the heel row (which rubs on the formation) and the gage row (which drills the borehole to the desired gage or diameter) as well as successive concentric rows terminating at the apex of the truncated cone having alternating tungsten carbide chisel inserts and diamond coated inserts. The

1 heel row adjacent the cone mouth opening alternates
flush mounted tungsten carbide inserts with harder
tungsten carbide inserts with a layer of
polycrystalline diamond bonded thereto. The alternating
5 gage row inserts extend from the cone surface and serve
to cut the gage of the borehole.

It is well known in the art to utilize flush type
inserts in the heel row of roller cones primarily to
minimize erosion of the cones due to the passage of
10 drilling fluid and formation detritus between the heel
and gage rows of the cones and the borehole wall. The
'099 patent, while it teaches alternating hard and soft
flush inserts in the heel row also teaches that it is
more important that the larger diameter rows,
15 particularly the gage row, be provided with an
intermingled pattern of soft and hard inserts to
facilitate drilling differing earthen formations.

Maintenance of a constant diameter borehole
throughout the drilling operation is of paramount
20 importance in cost-per-foot drilling costs. If a rock
bit should drill undergage it causes a following, same
diameter bit to pinch due to the undersized hole
condition. This usually results in a ruined rock bit
and is the cause of another trip out of the hole,
25 followed by a reaming operation, all of which is time
consuming and very costly. Moreover, directional
drilling of boreholes has become increasingly more
prevalent for more efficient extraction of petroleum
from known oil reserves. State of the art rock bits
30 such as the foregoing patent are ill suited for
directional drilling applications because the heel and
gage rows formed on the cones are primarily designed to
maintain the gage diameter of the hole.

Flush type heel row inserts ultimately act as a
35 passive bearing surface when the heel of the cone is in
contact with the borehole wall. When the entire heel
surface of each of the cones is in contact with the

1 borehole wall, the cones are subjected to tremendous
intrust loads. The intrust loads tend to pinch the
bit, damage the cone and journal bearings and cause
heat checking of the tungsten carbide inserts.

5 Where it becomes necessary to deviate from the
vertical in directional drilling operations, the bits
will not adequately invade the borehole sidewall to
effect a turn from the vertical. Thus, rock bits with
side cutting capability have a decided advantage over
10 state of the art roller cone rock bits.

U.S. Patent Number 5,131,480, hereby incorporated
by reference, teaches the use of extended tungsten
carbide inserts in a recessed heel row in a milled
tooth rotary cone rock bit. While this patented feature
15 greatly improved directional drilling capabilities, the
rounded projections on the heel row inserts somewhat
limited the rock shearing function necessary for
aggressive side cutting while turning from a straight
drill run. Also, the tungsten carbide wears, allowing
20 an undergauge condition.

It was found through experimentation that if
drilling energy is not put into shearing the rock, the
energy then converts into pushing the cone away from
the rock formation resulting in the heretofore
25 mentioned intrust condition with all of its
disadvantages.

Thus, it is desirable to have a roller cone rock
bit with enhanced side cutting capabilities to maintain
full gauge borehole diameter for vertical drilling
30 applications.

BRIEF SUMMARY OF THE INVENTION

A rotary cone rock bit for drilling boreholes in
an earthen formation has a rock bit body and a
35 plurality of rotary cones rotatively retained on
respective journal bearings on the rock bit body. A
plurality of cemented tungsten carbide inserts in

1 each of the rotary cones drill a borehole. A
circumferential gage row of cemented tungsten carbide
inserts in each of the rotary cones drills a borehole
to a desired diameter. A circumferential heel row
5 with extended ultra hard shaped cutters spaced within
the heel row serves to maintain a desired borehole
diameter. Each of the shaped cutters has an ultra
hard cutting edge arranged for shearing a borehole
wall in earthen formation as the rotary cone rotates
10 against a bottom of the borehole.

The hard wear material is preferably
polycrystalline diamond that protrudes from the heel
row of each cone. Preferably the cutting edges are
skewed for both shearing the side wall of the
15 borehole and deflecting debris away from the cone
bearings as the roller cones rotate on the bottom of
a borehole.

BRIEF DESCRIPTION OF THE DRAWINGS

20 The above noted features and advantages of the
present invention will be more fully understood upon
a study of the following description in conjunction
with the detailed drawings wherein:

FIGURE 1 is a perspective view of a sealed
25 bearing rotary cone rock bit;

FIGURE 2 is a partially cut away cross-section
of a roller cone mounted to a journal bearing ;

FIGURE 3 is an end view of the cone taken
through 3-3 of Figure 2 illustrating the heel surface
30 of the cone and the orientation of each of the shaped
diamond cutters equidistantly placed around the heel
row;

FIGURE 4 is an enlarged perspective view of a
single shaped diamond cutter illustrating the cutting
35 edge of the insert that may be oriented in the heel
row to aggressively shear into a side wall of a
formation and to deflect detritus from the bearing

1 surfaces as the cone rotates in a formation;

FIGURE 5 is an exploded perspective view,
partially in phantom, of an alternative embodiment
wherein the heel row is formed from a hard metal
5 conical ring element with diamond cutter segments
oriented and bonded thereto, the conical ring being
subsequently metallurgically attached to a conically
formed groove formed in the cone adjacent the heel
row;

10 FIGURE 6 is a section taken through 6-6 of
Figure 5 illustrating the diamond cutter segment
mounted to the conical heel row ring with a built up
backing portion behind each of the cutter segments
for support thereof;

15 FIGURE 7 is an exploded perspective view
partially in phantom of yet another alternative
embodiment showing a conical heel row ring element
with equidistantly and circumferentially spaced
shaped insert cutter pockets formed in the conical
20 ring, with shaped diamond inserts being oriented and
attached within the pockets;

FIGURE 8 is a perspective view of an alternative
diamond cutter with a hemispherical cutting end
forming an arcuate cutting surface;

25 FIGURE 9 is a perspective view of an alternative
diamond cutter insert with a back rake angle and a
convex cutting edge surface;

FIGURE 10 is a side view of the insert of Figure
9;

30 FIGURE 11 is a perspective view of another
embodiment of a diamond cutter insert with a flat or
slightly curved cutting face formed in a domed
insert, the diamond cutting face forming a back rake
angle;

35 FIGURE 12 is a side view of the insert of Figure
11;

FIGURE 13 is yet another embodiment of a diamond

1 cutter insert wherein the domed insert cap is layered
with polycrystalline diamond and a cutting edge is
formed by removing an angled portion through a plane
taken through the apex of the dome, the removed
5 section exposing the tungsten carbide base and a ring
of diamond which, at its leading edge serves to cut
the gage of a borehole; and

FIGURE 14 is a side view of the insert of Figure
13.

10

DESCRIPTION

Boreholes are commonly drilled with rock bits
having rotary cones with cemented carbide inserts
interference fitted within sockets formed by the
15 cones. Such a rock bit generally designated as 10 has
a steel body 20 with threads 14 formed at an upper
pin end and three depending legs 22 at its lower end.
Three cutter cones generally designated as 16 are
rotatively mounted on the three legs at the lower end
20 of the bit body. A plurality of cemented tungsten
carbide inserts 18 are press fitted or interference
fitted into insert sockets formed in the surface of
the cones 16. Lubricant is provided to the journals
19 (Fig. 2) on which the cones are mounted from each
25 of three grease reservoirs 24 in the body.

When the rock bit is used, it is threaded onto
the lower end of a drill string and lowered into a
well or borehole. The bit is rotated with the
carbide inserts in the cones engaging the bottom of
30 the hole. As the bit rotates, the cones 16 rotate on
the bearing journals 19 cantilevered from the body
and essentially roll around the bottom of the hole
25. The weight of the bit is applied to the rock
formation by the carbide inserts and the rock is
35 thereby crushed and chipped by the inserts. A
drilling fluid is pumped down the drill string to the
bottom of the hole and ejected from the bit body

1 through nozzles 26. The drilling fluid then travels
up the annulus formed between the outside drill pipe
wall and the borehole formation walls. The drilling
fluid provides cooling and removes the chips from the
5 bottom of the borehole.

With reference now to Figure 2, the lower
portion of the leg 22 provides the journal bearing 19
on which cone 16 rotates. The cone is retained on
the bearing by a plurality of cone retention balls 21
10 confined by a pair of opposing ball races formed in
the journal and the cone. The cone includes an
annular heel row 17 positioned between the gage row
inserts 15 and a bearing cavity 27 formed in the
cone. A multiplicity of protruding heel row insert
15 cutters generally designated as 30 are about
equidistantly spaced around the heel row 17. The
protruding heel row inserts 30 and the gage row
inserts 15 coact to primarily cut the gage diameter
of the borehole 25. The multiplicity of remaining
20 inserts 18 in concentric rows crush and chip the
earthen formation as heretofore described.

With reference now to Figures 3 and 4, each of
the heel row inserts or cutters 30 is, for example,
formed from a cemented tungsten carbide body 32
25 having a base end 40 and a cutter end 38. The cutter
end 38 supports an ultra hard cutter element 34
(preferably polycrystalline diamond) that is, for
example, metallurgically bonded or brazed to the
cutting end at juncture 37. An end backup support 38
30 for the ultra hard cutter is important in that it
serves to help prevent separation of the cutter from
the carbide body 32. In addition, the backup support
38 allows the trailing edge 39 of the cutter 34 to be
supported to prevent cutter breakage due to elastic
35 rebound that often occurs during drilling operations.

The cutter element 34, for example, defines a
straight cutting edge 36 that may be substantially

1 radially oriented with respect to an axis of the cone
16. The cutting edge 36 may however, be slightly
convex as is illustrated with respect to Figures 8
and 9.

5 With specific reference to Figure 3, each of the
cutters 30 is preferably skewed with a negative side
rake angle "A" with respect to a radial line from the
axis of the cone. This orientation effectively
shears the formation while simultaneously directing
10 the debris away from the sealed bearing surfaces
formed between the cone 16 and the journal 19 when
the cone rotates in direction indicated by an arrow
29. The side rake angle may be between 2 and 20
degrees. The preferred side rake angle is 5°. The
15 side rake angle distributes the forces subjected to
the cutting edge effectively to prevent "balling" of
the bit (a condition where debris piles up against
the cutting face of the cutting element or edge
loading of the cutting edge of the cutters.

20 Each of the heel row diamond insert cutters 30
is preferably interference fitted within an insert
retention socket 31 formed in the heel row. The
diamond material may be composed of polycrystalline
material pressed in a super pressure press of the
25 type taught in U.S. Patent Number 4,604,106.
Moreover, the diamond cutters may be fabricated from
a composite of tungsten carbide material impregnated
with diamond particles. A process for making such
material is set forth in U.S. Patent Numbers
30 4,966,627 and 5,045,092. Additionally, the ultra
hard cutters may be fabricated from composites of
cubic boron nitride (CBN) and refractory metal
carbides such as tungsten carbide.

The exploded perspective view of Figure 5
35 illustrates an alternative embodiment of the
invention wherein the aggressive heel row cutting
action is incorporated in a conically shaped ring 56

1 that is insertable within a complementary groove 54
formed in a cone generally designated as 50. Diamond
cutter segments 60 are metallurgically bonded to a
recess 59 formed in the ring 56 (Fig. 6). Each of
5 the diamond cutters 60 is preferably positioned with
a negative side rake angle with respect to a radial
line from an axis of the cone 50 such as that shown
in Figure 3. Furthermore, each cutter 60 is backed
up by support 58 formed on the conical ring 56.

10 The ring may, for example, be machined from a
metal such as steel or it may be formed in a mold
utilizing powdered tungsten carbide material; the
diamond cutter recess 59 and backup portion 58 being
formed in a female mold (not shown). The diamond
15 cutters 60 are subsequently metallurgically bonded
(preferably brazed) into their recesses 59. The
finished ring 56 is then brazed within the groove 54
in the cone. If desired, the ring could be segmented
into, for example, four 120° segments and brazed in
20 place for ease of fabrication.

Figure 7 is yet another embodiment of the
invention wherein a conical ring 76 (similar to the
ring 56 of Figure 5) is formed either by a powder
metallurgy process or by machining. The conical ring
25 includes a series of equidistantly spaced insert
sockets 78 around the heel row surface of the ring.
Diamond cutter inserts generally designated as 80 are
brazed within each of the sockets 78 and the
completed ring assembly is subsequently
30 metallurgically bonded within a complementary groove
74 formed in heel surface 72 of the cone. The
inserts 80 are fabricated with, for example, a
straight diamond cutting edge 86 and a base portion
having a depth sufficient to be bonded within the
35 sockets formed in the conical ring. The cutting edge
86 is angled with a negative side rake angle with
respect to a radial line from an axis of the cone 70

1 at an angle of up to 35 degrees. Again, the ring 70
may be fabricated from cemented tungsten carbide or
similar erosion resisting material.

5 Figure 8 illustrates another embodiment wherein
the insert 130 is hemispherical at its cutting end.
The cutting edge 136 on a half disc diamond segment
134 secured the insert body is arcuate conforming to
the circular end of the insert. A backup portion 139
10 serves to back up the diamond composite bonded at
junction 135 of the exposed end of the cutter. A
braze joint 137, for example, secures the half disc
diamond segment 134 to the backup portion.

Figures 9 and 10 illustrate an alternative
embodiment of diamond insert 240 similar to the
15 insert 30 of Figure 4. The cutting face 243,
however, is arcuate or convexly curved and raked back
at an angle B that is preferably between 0 and 75
degrees relative to a tangent to the heel row to
maintain the diamond cutting face 243 in a
20 compressive mode while maintaining maximum shearing
action as the cutting edge 246 works against a rock
formation. A back support area 239 serves to support
the curved diamond cutter 234, especially during
drilling operations that often result in elastic
25 rebound action that the cutters are subjected to.

Figures 11 and 12 illustrate still another
embodiment having a domed tungsten carbide insert 340
with an angled plane surface 345 formed in a leading
edge thereof. A diamond cutter 343 is bonded to the
30 surface 345 at a back rake angle of about 45°.

The diamond insert of Figures 13 and 14 is a
domed diamond layered insert 440 with a portion of
the dome removed along a plane transverse to an axis
of the insert to form a leading cutter edge 446 that
35 is aligned substantially in the direction of rotation
of the cone. The plane of the section cut through
the dome is angled about 80 degrees relative to the

1 axis of the insert. The arcuate diamond cutting edge
446 is supported by the tungsten carbide portion 439
exposed behind the cutter face 443. The asymmetrical
cutting edge 446 created by the angled "slice"
5 through the apex of the dome (shown in phantom in
Fig. 14) facilitates the orientation of the rounded
cutting edge with respect to the heel row 17 as
illustrated in Figure 3.

It will of course be realized that various
10 modifications can be made in the design and operation
of the present invention without departing from the
spirit thereof. Thus, while the principal preferred
construction and mode of operation of the invention
have been explained in what is now considered to
15 represent its best embodiments, it should be
understood that within the scope of the appended
claims, the invention may be practiced otherwise than
as specifically illustrated and described.

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1 WHAT IS CLAIMED IS:

1. A rotary cone rock bit for drilling
boreholes in an earthen formation comprising:

 a rock bit body;

5 a plurality of rotary cones rotatively retained
on respective journal bearings on the rock bit body;
 a plurality of cemented tungsten carbide inserts
in each of the rotary cones;

 a circumferential gage row of cemented tungsten
10 carbide inserts in each of the rotary cones for
drilling a borehole to a desired diameter; and

 a circumferential heel row with extended ultra
hard shaped cutters spaced within the heel row, each
of said shaped cutters having ultra hard cutting
15 edges arranged for shearing a borehole wall in
earthen formation as the rotary cone rotates against
a bottom of the borehole, the shaped cutters serving
to maintain a desired borehole diameter.

20 2. A rock bit as set forth in claim 1 wherein
the ultra hard shaped cutter edge has a backup
support.

 3. A rock bit as set forth in either one of
25 claims 1 or 2 wherein the cutting edges of the shaped
cutters are skewed relative to a radial line from the
axis of the cone at a side rake angle for diverting
formation debris away from bearing surfaces formed
between the rotary cone and the journal bearing.

30 4. A rock bit as set forth in any one of the
preceding claims wherein the ultra hard cutting edges
of the shaped cutters extending from said heel row
are formed from diamond.

35 5. A rock bit as set forth in any one of the
preceding claims wherein the cutting edge forms a

1 substantially straight line across the cutter end.

6. A rock bit as set forth in any one of the
preceding claims wherein the cutting edge is convex.
5

7. A rock bit as set forth in any one of the
preceding claims wherein a face of the cutter edge
has a back rake angle with respect to a tangent to
the heel row.

10 8. A rock bit as set forth in any one of the
preceding claims wherein the second cutter end is
about half dome shaped, the diamond cutting edge
forming an arcuate surface conforming to the shape of
15 the dome.

9. A rock bit as set forth in any one of the
preceding claims wherein the cutting edges of the
shaped cutters comprise polycrystalline diamond
20 bonded to a tungsten carbide substrate.

10. A rock bit as set forth in any one of the
preceding claims wherein the side rake angle is
between two and twenty degrees.
25

11. A rock bit as set forth in wherein the side
rake angle is five degrees.

12. A rock bit as set forth in any one of the
30 preceding claims wherein the extended ultra hard
shaped cutters are fabricated from composites of
cubic boron nitride and tungsten carbide.

13. A rock bit as set forth in any one of the
35 preceding claims wherein the extended ultra hard
shaped cutters are fabricated from composites of
diamond and tungsten carbide.

1 14. A rock bit as set forth in any one of the
preceding claims wherein the shaped cutters are
tungsten carbide bodied inserts having a first base
end and a second cutter end, the second cutter end
5 comprising polycrystalline diamond bonded to a
tungsten carbide substrate, the second cutting end of
the body serving as backup support for the diamond.

10 15. A rock bit as set forth in any one of
claims 1 to 13 comprising a circumferential heel row
ring secured within a complementary heel row groove
in the rotary cone, the ring comprising pockets for
mounting the shaped cutters and backup means for
supporting the shaped cutters.

15 16. A rock bit as set forth in claim 15 wherein
the heel row ring is fabricated from erosion
resistant tungsten carbide material.

20 17. A rock bit as set forth in either one of
claims 15 or 16 wherein the heel row ring comprises a
plurality of insert holes around the face of the
ring, and a plurality of cemented tungsten carbide
inserts in the holes, each insert comprising a layer
25 of polycrystalline diamond bonded to the tungsten
carbide insert for forming the cutting edge.

30 18. A rock bit as set forth in any one of
claims 15 to 17 wherein the ring is segmented into
two or more segments, each segment being secured to
the cone.

35 19. A rock bit substantially as described and
illustrated.

Patents Act 1977
 Examiner's report to the Comptroller under Section 17
 (Main Search report)

Application number
 GB 9400012

Relevant Technical Fields

- (i) UK Cl (Ed.M) E1F (FFD, FGA, FGB, FGC)
 (ii) Int Cl (Ed.5) E21B

Search Examiner
 D J HARRISON

Date of completion of Search
 31 MARCH 1994

Databases (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-
 1 TO 19

(ii) ONLINE DATABASES: WPI

Categories of documents

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Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0511547 A (SMITH INTERNATIONAL INC) whole document, but see particularly heel row inserts 25 and column 6 lines 50-54	1, 4
X	US 5119714 A (HUGHES TOOL CO) whole document, but see particularly heel row inserts 83, Figure 11	1, 4

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).